

Office of
Aeronautics and
Space
Technology



PATHFINDER

SURFACE EXPLORATION, IN-SPACE OPERATIONS, AND
SPACE TRANSFER

*Technology for NASA Future Missions
an AIAA/NASA OAST Conference*

September 12-13, 1988
The Capital Hilton
Washington, DC

JOHN MANKINS
PATHFINDER PROGRAM MANAGER

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PATHFINDER PROGRAM AREA SURFACE EXPLORATION

~~OAST~~

TECHNOLOGY NEEDS

- PILOTED AND AUTOMATED SURFACE MOBILITY AND MANIPULATION SYSTEMS
- MOBILE AND STATIONARY SURFACE POWER SYSTEMS (SOURCES AND STORAGE)
- ADVANCED SPACE COMPUTING, WITH GROUND & ON-BOARD AUTONOMOUS SYSTEMS
- MULTIPLE SENSORS (REMOTE AND LOCAL)
- SURFACE MATERIALS, STRUCTURES, AND MECHANISMS
- TECHNOLOGIES FOR SURFACE SCIENCES (E.G., SAMPLING AND IN SITU ANALYSIS)

PATHFINDER PROGRAM AREA SURFACE EXPLORATION

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ELEMENT PROGRAMS

- PLANETARY ROVER
- SAMPLE ACQUISITION, ANALYSIS,
& PRESERVATION
- AUTONOMOUS LANDER
- SURFACE POWER
- PHOTONICS

PATHFINDER PLANETARY ROVER

OAST

TECHNOLOGIES

- MOBILITY
- AUTONOMOUS GUIDANCE
- SAMPLING ROBOTICS
- ROVER POWER

MISSION APPLICATIONS

- LUNAR ROVERS (Piloted & Robotic)
- MARS ROVERS (Piloted & Robotic)
- OTHER ROBOTIC EXPLORATION AND
SAMPLE RETURN MISSIONS (e.g., CNSR)

PATHFINDER PLANETARY ROVER

OAST

PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
Information Sciences And Human
Factors Division
- **LEAD NASA FIELD CENTER:**
Jet Propulsion Laboratory
- **PARTICIPATING CENTERS:**
Ames Research Center
Langley Research Center
Lewis Research Center
- **FY 1989 BUDGET: \$ 5 MILLION**

PATHFINDER SAMPLE ACQUISITION, ANALYSIS & PRESERVATION

CAST

TECHNOLOGIES

- **SAMPLING TOOLS & SYSTEMS**
- **CHEMICAL/PHYSICAL ANALYSIS SENSORS**
- **PRESERVATION (e.g., Materials, Seals)**

MISSION APPLICATIONS

- **LUNAR ROVERS (Piloted & Robotic)**
- **MARS ROVERS (Piloted & Robotic)**
- **OTHER SAMPLE RETURN MISSIONS (CNSR)**

PATHFINDER
SAMPLE ACQUISITION, ANALYSIS, & PRESERVATION

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
Materials and Structures Division
- **LEAD NASA FIELD CENTER:**
Jet Propulsion Laboratory
- **PARTICIPATING CENTERS:**
Ames Research Center
Johnson Space Center
- **FY 1989 BUDGET: \$ 1 MILLION**

PATHFINDER AUTONOMOUS LANDER

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TECHNOLOGIES

- **GN&C (Terminal Descent)**
- **SENSORS**
- **SYSTEMS AUTONOMY**
- **MECHANIZATION/MECHANICAL SYSTEMS**

MISSION APPLICATIONS

- **LUNAR OUTPOST OPERATIONS VEHICLES**
- **ROBOTIC SOLAR SYSTEM EXPLORATION**
- **PILOTED MARS EXPEDITION**

PATHFINDER AUTONOMOUS LANDER

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
**Information Sciences & Human Factors
Division**
- **LEAD NASA FIELD CENTER:**
Johnson Space Center
- **PARTICIPATING CENTERS:**
**Ames Research Center
Jet Propulsion Laboratory**
- **FY 1989 BUDGET: \$ 1 MILLION**

PATHFINDER SURFACE POWER

CAST

TECHNOLOGIES

- ADVANCED PHOTOVOLTAICS
- POWER STORAGE (e.g, Fuel Cells)
- ENVIRONMENTAL COUNTERMEASURES

MISSION APPLICATIONS

- LUNAR OUTPOST START-UP
- PILOTED MARS EXPEDITIONS
- OTHER SPACECRAFT (Earth-orbit, Transfer)

PATHFINDER SURFACE POWER

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
Propulsion, Power, and Energy
Division
- **LEAD NASA FIELD CENTER:**
Lewis Research Center
- **PARTICIPATING CENTERS:**
Jet Propulsion Laboratory
(Not funded in FY'89)
- **FY 1989 BUDGET: \$1.5 MILLION**

PATHFINDER PHOTONICS

OAST

TECHNOLOGIES

- **FAULT-TOLERANT ELECTRONICS/
PHOTONICS SYSTEM ARCHITECTURES**
- **PHOTONICS COMPONENTS
(Sensors, Memories, Input/Output Components,
Image Processing)**

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MISSION APPLICATIONS

- **LUNAR OUTPOST SYSTEMS (e.g., Observatories)**
- **PILOTED PHOBOS/MARS EXPEDITIONS**
- **ROBOTIC SOLAR SYSTEM EXPLORATION
(e.g., Autonomous Landers, Planetary Rovers)**
- **ADVANCED EARTH-ORBITING OPERATIONS**

PATHFINDER PHOTONICS

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
Information Sciences & Human Factors
Division
- **PARTICIPATING CENTERS:**
Ames Research Center
Jet Propulsion Laboratory
Johnson Space Center
Langley Research Center
- **INITIATION DEFERRED TO 1990**

PATHFINDER PROGRAM AREA IN-SPACE OPERATIONS

CAST

TECHNOLOGY NEEDS

- AUTOMATED AND SEMI-AUTONOMOUS OPERATIONS (E.G., RENDEZVOUS & DOCKING)
- ASSEMBLY, CONSTRUCTION, AND TESTING OF LARGE SPACE SYSTEMS (IN ORBIT AND ON SURFACES)
- MANAGEMENT AND LONG-TERM STORAGE OF CRYOGENIC FLUIDS
- HIGH-CAPACITY POWER SYSTEMS (E.G., NUCLEAR)
- HIGH-RATE SPACE COMMUNICATIONS SYSTEMS
- IN SITU RESOURCE UTILIZATION TECHNIQUES AND HARDWARE (E.G., FUEL PRODUCTION AND MINING)

PATHFINDER PROGRAM AREA IN-SPACE OPERATIONS

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ELEMENT PROGRAMS

- AUTONOMOUS RENDEZVOUS & DOCKING
- IN-SPACE ASSEMBLY AND CONSTRUCTION
- CRYOGENIC FLUID DEPOT
- SPACE NUCLEAR POWER (SP-100)
- RESOURCE PROCESSING PILOT PLANT
- OPTICAL COMMUNICATIONS

PATHFINDER AUTONOMOUS RENDEZVOUS & DOCKING

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TECHNOLOGIES

- **SENSORS (e.g., Laser Ranging, Radars)**
- **GN&C (Fault-Tolerant, On-Board)**
- **SYSTEM AUTONOMY**

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MISSION APPLICATIONS

- **SPACE TRANSFER VEHICLES (Earth & Lunar)**
- **PILOTED MARS EXPEDITION**
- **ROBOTIC SAMPLE RETURN MISSIONS (MRSR)**

PATHFINDER AUTONOMOUS RENDEZVOUS & DOCKING

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Information Sciences & Human Factors
Division**
- **LEAD NASA FIELD CENTER:
Johnson Space Center**
- **PARTICIPATING CENTERS:
Jet Propulsion Laboratory
Marshall Space Flight Center**
- **FY 1989 BUDGET: \$1 MILLION**

PATHFINDER IN-SPACE ASSEMBLY AND CONSTRUCTION

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TECHNOLOGIES

- **LARGE-SCALE MANIPULATION SYSTEMS
(Including highly flexible manipulators)**
- **JOINING TECHNIQUES (e.g., Welding)**
- **PRECISION STRUCTURE ALIGNMENT/ADJUSTMENT**

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MISSION APPLICATIONS

- **LUNAR OUTPOST STAGING**
- **MARS MISSION STAGING (Robotic, Piloted)**
- **ADVANCED SPACE STATION OPERATIONS**
- **EARTH-ORBIT OBSERVATORY STAGING**

PATHFINDER IN-SPACE ASSEMBLY & CONSTRUCTION

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Materials and Structures Division**
- **LEAD NASA FIELD CENTER:
Langley Research Center**
- **PARTICIPATING CENTERS:
Jet Propulsion Laboratory
Johnson Space Center
Marshall Space Flight Center**
- **FY 1989 BUDGET: \$1 MILLION**

PATHFINDER CRYOGENIC FLUID DEPOT

CAST

TECHNOLOGIES

- **LONG-TERM CRYOGEN CONTAINMENT & MANAGEMENT**
- **REFRIGERATION COMPONENTS/SYSTEMS**
- **FLUID TRANSFER COMPONENTS/SYSTEMS**

MISSION APPLICATIONS

- **LUNAR OUTPOST STAGING/OPERATIONS**
- **MARS MISSION STAGING (Robotic, Piloted)**
- **ADVANCED SPACE STATION OPERATIONS**
- **ASTROPHYSICS OBSERVATORY SERVICING**

PATHFINDER CRYOGENIC FLUID DEPOT

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Propulsion, Power, and Energy
Division**
- **LEAD NASA FIELD CENTER:
Lewis Research Center**
- **PARTICIPATING CENTERS:
Johnson Space Center
Marshall Space Flight Center**
- **FY 1989 BUDGET: \$3 MILLION**

PATHFINDER SPACE NUCLEAR POWER (SP-100)

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TECHNOLOGIES

- **REFRACTORY METAL REACTOR**
- **FUEL PINS**
- **HIGH-TEMPERATURE CONTROL SYSTEM**
- **LIQUID-METAL THERMOELECTRIC MAGNETIC PUMP**
- **THERMAL-TO-ELECTRIC CONVERSION**
- **HEAT-PIPE HEAT-REJECTION SYSTEMS**

MISSION APPLICATIONS

- **LUNAR/MARS OUTPOSTS**
- **PILOTED MARS EXPEDITION**
- **ADVANCED EARTH-ORBIT OPERATIONS**
- **ROBOTIC SOLAR SYSTEM EXPLORATION
(Nuclear Electric Propulsion/Power)**

PATHFINDER RESOURCE PROCESSING PILOT PLANT

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TECHNOLOGIES

- **MATERIALS ANALYSIS SENSORS**
- **MECHANICAL SEPARATION/EXTRACTION**
- **ELECTRO-CHEMICAL SEPARATION/EXTRACTION**
- **ROBOTIC MATERIALS COLLECTION/HANDLING**

MISSION APPLICATIONS

- **LUNAR OUTPOST RESOURCE PLANT**
- **MARS RESOURCE PLANT**
- **OTHER SOLAR SYSTEM RESOURCE
UTILIZATION**

PATHFINDER RESOURCE PROCESSING PILOT PLANT

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Materials and Structures Division**
- **LEAD NASA FIELD CENTER:
Johnson Space Center**
- **PARTICIPATING CENTERS:
Jet Propulsion Laboratory**
- **INITIATION DEFERRED TO 1990**

PATHFINDER OPTICAL COMMUNICATIONS

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TECHNOLOGIES

- **ACQUISITION & TRACKING SYSTEMS**
- **CONTROL SYSTEMS**
- **TELESCOPE/LASER SYSTEMS**

MISSION APPLICATIONS

- **LUNAR OUTPOST**
- **PILOTED MARS EXPEDITIONS**
- **ROBOTIC SOLAR SYSTEM EXPLORATION**

PATHFINDER OPTICAL COMMUNICATIONS

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
Information Sciences & Human Factors
Division
- **PARTICIPATING CENTERS:**
Goddard Space Flight Center
Jet Propulsion Laboratory
- **INITIATION DEFERRED TO 1990**

PATHFINDER PROGRAM AREA SPACE TRANSFER

CAST

TECHNOLOGY NEEDS

- ADVANCED CHEMICAL PROPULSION SYSTEMS
(DESIGNED FOR SPACE-BASING/MAINTENANCE)
- HIGH-THRUST IN-SPACE PROPULSION FOR
HUMAN MISSION STAGING
- LUNAR-LEO AND INTERPLANETARY AERO-
BRAKING (TPS, GN&C, AEROTHERMODYNAMICS)
- DESCENT/ASCENT PROPULSION FOR MOON/
MARS APPLICATIONS
- HIGH-EFFICIENCY ELECTRIC PROPULSION FOR
CARGO TRANSFER

PATHFINDER PROGRAM AREA SPACE TRANSFER

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ELEMENT PROGRAMS

- CHEMICAL TRANSFER PROPULSION
- HIGH-ENERGY AEROBRAKING
- CARGO VEHICLE PROPULSION

PATHFINDER CHEMICAL TRANSFER PROPULSION

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TECHNOLOGIES

- **LIQUID OXYGEN/HYDROGEN ENGINES**
- **HIGH-HEAT COMBUSTERS**
- **HIGH-PRESSURE TURBO-MACHINERY**
- **INTEGRATED DIAGNOSTICS/CONTROLS**

MISSION APPLICATIONS

- **LUNAR OUTPOST OPERATIONS VEHICLES**
- **ROBOTIC SOLAR SYSTEM EXPLORATION**
- **PILOTED MARS EXPEDITION**
- **ADVANCED EARTH-ORBIT OPERATIONS**

PATHFINDER CHEMICAL TRANSFER PROPULSION

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Propulsion, Power, and Energy
Division**
- **LEAD NASA FIELD CENTER:
Lewis Research Center**
- **PARTICIPATING CENTERS:
Marshall Space Flight Center
(Not funded in FY'89)**
- **FY 1989 BUDGET: \$4 MILLION**

PATHFINDER HIGH-ENERGY AEROBRAKING

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TECHNOLOGIES

- **AEROBRAKE CONFIGURATIONS**
- **AEROTHERMODYNAMICS**
- **GN&C (On-Board, Autonomous, Adaptive)**
- **THERMAL PROTECTION SYSTEMS**

MISSION APPLICATIONS

- **LUNAR OUTPOST OPERATIONS**
- **ROBOTIC/PILOTED MARS EXPEDITION**
- **ROBOTIC SOLAR SYSTEM EXPLORATION**

PATHFINDER HIGH-ENERGY AEROBRAKING

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Aerodynamics Division**
- **LEAD NASA FIELD CENTER:
Langley Research Center**
- **PARTICIPATING CENTERS:
Ames Research Center
Johnson Space Center
Jet Propulsion Laboratory**
- **FY 1989 BUDGET: \$1.5 MILLION**

PATHFINDER CARGO VEHICLE PROPULSION

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TECHNOLOGIES

- **MAGNETOPLASMA DYNAMIC THRUSTERS (MPD)
(e.g., Cathodes, Controls, Magnetic Fields, High
Power Level Systems)**
- **ION ENGINES (Testing)**
- **LONG-LIFE TESTING**

MISSION APPLICATIONS

- **LUNAR OUTPOST OPERATIONS (OTV/Ion)**
- **PILOTED MARS EXPEDITION (Cargo Vehicle)**
- **ROBOTIC SOLAR SYSTEM EXPLORATION (Ion)**

PATHFINDER CARGO VEHICLE PROPULSION

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PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:
Propulsion, Power, and Energy
Division**
- **LEAD NASA FIELD CENTER:
Lewis Research Center**
- **PARTICIPATING CENTERS:
Jet Propulsion Laboratory**
- **INITIATION DEFERRED TO 1990**

PATHFINDER THRUSTS AND ELEMENTS

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MISSION STUDIES

TRANSFER VEHICLES

CHEMICAL TRANSFER PROPULSION
CARGO VEHICLE PROPULSION
HIGH ENERGY AEROBRAKING
AUTONOMOUS LANDER
FAULT-TOLERANT SYSTEMS

EXPLORATION

PLANETARY ROVER
SAMPLE ACQUISITION, ANALYSIS
& PRESERVATION
SURFACE POWER
OPTICAL COMMUNICATIONS

OPERATIONS

AUTONOMOUS RENDEZVOUS AND DOCKING
RESOURCE PROCESSING PILOT PLANT
IN-SPACE ASSEMBLY & CONSTRUCTION
CRYOGENIC FLUID DEPOT
SPACE NUCLEAR POWER (SP100)

HUMANS-IN-SPACE

EVA/SUIT
HUMAN PERFORMANCE
CLOSED-LOOP LIFE SUPPORT

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